Talk of the Town: Discovering Open Public Data via Voice Assistants

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Abstract

Access to public data in the United States and elsewhere has steadily increased as governments have launched geospatially-enabled web portals like Socrata, CKAN, and Esri Hub. However, data discovery in these portals remains a challenge for the average user. Differences between users' colloquial search terms and authoritative metadata impede data discovery. For example, a motivated user with expertise can leverage valuable public data about transportation, real estate values, and crime, yet it remains difficult for the average user to discover and leverage data. To close this gap, community dashboards that use public data are being developed to track initiatives for public consumption; however, dashboards still require users to discover and interpret data. Alternatively, local governments are now developing data discovery systems that use voice assistants like Amazon Alexa and Google Home as conversational interfaces to public data portals. We explore these emerging technologies, examining the application areas they are designed to address and the degree to which they currently leverage existing open public geospatial data. In the context of ongoing technological advances, we envision using core concepts of spatial information to organize the geospatial themes of data exposed through voice assistant applications. This will allow us to curate them for improved discovery, ultimately supporting more meaningful user questions and their translation into spatial computations.

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1 Open Data: Of, By, and For the People?

Open data, also called public sector information, aspire to increase the transparency of government activities and their accountability to the public [10]. In the United States, mandates for open data are often satisfied in part by the adoption of platforms, like CKAN and ArcGIS Hub, which mediate public access to government data catalogs. The platforms often include both geospatial (e.g. parcel maps) and non-geospatial data (e.g. tax tables).

However, the production, maintenance, and dissemination of such authoritative open public data is costly for providers and the effort does not guarantee increased public engagement [6]. Furthermore, work remains to be done to help governments keep track of the direct and indirect benefits of their open data policies, measured in part by tracking data reuse [2].

Impediments to the uptake of open public data include challenges with data discovery and usability. *Discovery* is understood broadly as a mode of exploratory search that involves browsing for task appropriate data, while *usability* describes the fitness of data for a defined task[1]. A major impediment to data discovery in human-system communication is reflected by the "vocabulary problem" [5], in which users rarely agree on what to call the things that they want to find. This makes effective keyword-based search and discovery difficult to accomplish in public open data portals. To address this problem, some open data portals like Esri's ArcGIS Hub have partnered with community organizations to develop ontologies that map the terms used to describe community level initiatives from authoritative vocabularies (e.g. the USGS Thesaurus) to users' colloquial terminology [8].

While this strategy addresses data discovery, it does not address underlying issues with data usability. Even if users are better able to identify task-appropriate data, they generally do not know how to assess the fitness of data for a given task and are still expected to manipulate and analyze data to gain insights. Given these constraints, services like data dashboards are being developed, allowing users to track vital community issues (e.g. pedestrian fatalities[2]) without requiring them to manipulate, clean, or visualize data. Even more empowering are alternative modalities, such as those offered by voice assistants, which are growing in popularity[3] and have implications for open public data discovery and use. Governments have suggested that voice assistants might offer new interfaces for connecting community members to public services and information exposed through open public data portals.

In this paper, we explore the current capabilities of various voice assistants under development by local governments across the United States. We focus on the application areas that these systems are designed to address and examine how (if at all) they leverage geospatial data. Next, we discuss the challenges that voice assistants face when answering geospatial questions. Finally, we envision using core concepts of spatial information [7] to organize the geospatial themes of data that users want to discover, with the goal of supporting a broader range of user questions and spatial computations on them. We focus primarily on improvements to discovery for existing systems that also carry benefits for data usability.

2 State of the Art for Government Voice Assistants

Voice assistants are now widely available on commercial smart speakers, such as Google Assistant and Amazon Alexa. A recent survey[4] has projected that half of all U.S. homes will own smart speakers by the end of 2019. The same survey also reported that the most common interactions with voice services include asking questions, performing online searches, performing basic research like confirming information, and asking for directions.

While today's voice assistants are used to control home automation systems and perform other basic daily tasks, interest has shifted to more intelligent interactions such as enabling natural conversations and answering questions. Users are able to ask questions about real-

[1] https://www.force11.org/group/fairgroup/fairprinciples
[2] http://visionzero.lacity.org/map/
[3] https://www.citylab.com/solutions/2018/10/amazon-alexa-smart-speakers-city/573412/
[4] https://www.cmo.com/features/articles/2018/9/7/adobe-2018-consumer-voice-survey.html

time information, such as *what time it is now?* and *what will the weather be like tomorrow?* When users talk to a voice assistant, their spoken words can be converted to text by APIs (e.g. Amazon's automatic speech recognition[5] and Google's Speech-to-Text API[6]). The diversity of expression in human language has posed enormous difficulties to language understanding. With the state-of-the-art natural language understanding (NLU) techniques, including syntax analysis (e.g. tokenization, identifying part-of-speech), entity recognition (e.g. organization, person, location), sentiment analysis, and intent and topic detection, machines are able to "understand" user questions. By detecting the given topic and intent, related information and potential answers are retrieved from various databases like Wikipedia, Google's knowledge graphs, and Microsoft's concept graphs. Retrieved information is then used to generate responses using different methods, such as rule-based and generative methods. The responses are then converted from text back to speech to answer user questions conversationally.

Voice assistant technology is now being leveraged to retrieve and reason on open public data through the development of skills (which are essentially micro tasks). In 2017, Esri prototyped an early government voice assistant application called Sonar[7]. It offered a chatbot that completed predefined tasks and addressed standard questions about a given community by leveraging open data available through Esri Hub. As shown in Figure 1, Sonar performs lookups on data matching the themes described in a user's query at a defined location. Users can ask about city services (e.g., trash pickup), safety (e.g., crimes), and transportation (e.g., bus routing). Sonar facilitates both open public data discovery and use by templatizing a set of intents designed to perform basic computations on geospatial data. In other words, Sonar provides a set of "core questions" that a community member would want to ask, and maps them to available, thematically relevant data, using location as context. Thus, governments can build additional skills upon Sonar's foundation.

Since the advent of Sonar, many U.S. cities have developed ad hoc voice assistant applications. Many are designed to reduce administrative burdens, such as "311 information" calls. For example, the Alexa skills developed for Albuquerque, New Mexico[8] allow residents to register complaints about graffiti, weeds, abandoned vehicles, and ask questions about city-owned facilities, like fee information for public parks. Raleigh, North Carolina[9] also allows residents to ask questions about the government, such as trash pickup days or elected representatives for a given neighborhood. Similarly, specific city departments, like New York City's Department of Environmental Protection[10], have created Alexa skills that allow residents to check their water usage and pay their bills. Los Angeles, California[11] has released several voice applications that provide residents with local information about recent earthquakes. The earthquake alert works on the Google Home system, which harvests USGS seismic data to notify residents of recent earthquake events based on the location of their device. The Alexa skills of Johns Creek, Georgia[12] are robust, continuously mining the city's open data portal to provide updated information about zoning and road closures.

These applications all work by knowing where to find open public data and how to use it in order to answer typical questions that people ask about government. Today, many

[5] https://developer.amazon.com/alexa-skills-kit/asr
[6] https://cloud.google.com/speech-to-text/
[7] https://github.com/Esri/sonar
[8] https://www.cabq.gov/alexa
[9] https://www.raleighnc.gov/home/news/content/CorNews/Articles/AlexaApp.html
[10] https://www1.nyc.gov/html/dep/html/customer_assistance/amazon-alexa.shtml
[11] https://assistant.google.com/services/a/uid/00000096ea087604?hl=en
[12] https://www.amazon.com/City-of-Johns-Creek-GA/dp/B07BHPGDR1

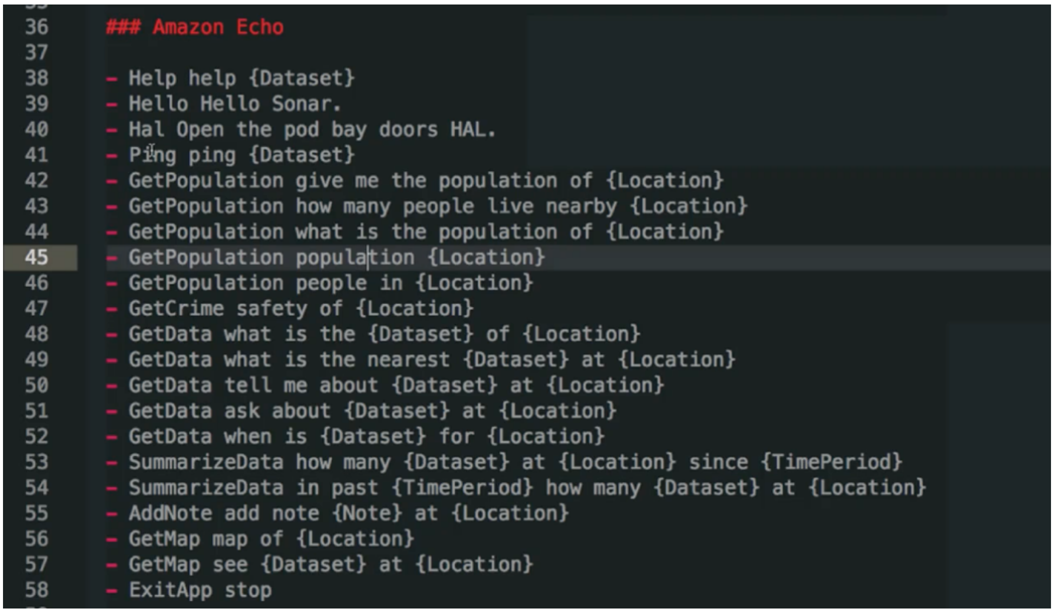

Figure 1 A list of the six intents (*ping, get population, get data, summarize data, add note,* and *get map*) accessible to users through the Sonar project's Alexa skill.

applications are built on top of voice assistant-accessible databases that contain standardized open public data (e.g. government data catalogs exposed through Esri's Open Data Hub). However, new trends such as the uptake of the schema.org Dataset standard[13] for the annotation of open public metadata (e.g. in Google Dataset Search[14]) enable the discovery of open public data through search engines [3]. As public data discoverability increases for the average user, it will also likely increase for the average voice assistant application. Thus, as it becomes easier for humans and machines to discover open public data, how can data be organized to facilitate use? We propose that time and space, inherent to geospatial data in particular, makes the themes that they are "about" more amenable to such curation.

3 Geospatial Limitations of Government Voice Assistants

The prospect for data discovery and question answering in the applications described in Section 2 is promising. Many municipalities are working to rapidly expand the skills that their voice assistants use to help answer questions and engage their communities. This is a reasonable tactic because it is likely that the efficacy of voice assistants will improve greatly over the next decade. These systems are synthesizing factual data with real-time computational abilities, using semantic technologies to answer increasingly complex questions.

However, we have observed two problems with this trend, which are even more evident when it comes to addressing geospatial questions: 1) voice assistant applications frequently bypass discovery, and 2) governments are building unsustainable skills. The first problem means that a system supplies an answer to a question without first allowing a user to explore available data. This may not seem like a problem when considering the alternative: a voice

[13] https://schema.org/Dataset
[14] https://toolbox.google.com/datasetsearch

assistant that would conversationally list available data. This mode of interaction would be tedious and far less efficient than exploring data by using a graphical browser. In a way, voice assistants are perceived to have abilities like those of a question-answering oracle. These question-answering systems bypass the process of manually discovering, manipulating, using, and reasoning on data themselves. In many cases, users often quickly accept the top suggestions by search engines[15]. However, much of the value of open data, especially open geospatial data, is the ability to explore and synthesize information, and conduct visual analysis. This is not possible with a voice assistant. What would be optimal for discovery is to make voice assistants more conversational. If a voice assistant application creates an index of datasets based on generic concepts that a user is familiar with, such as *objects* and *networks*, then the system could conversationally suggest relevant datasets.

The second problem is that if governments continue to build skills in their current manner, after a few years, they will likely have to maintain many heterogeneous (geospatial) tasks that will also be hard to improve. In other words, building skills in this manner is unsustainable. Furthermore, most of the aforementioned examples of applications in Section 2 are not explicitly geospatial. Those that could be considered geospatial work by retrieving pre-generated data from factual databases (e.g. water usage), and some leverage near real-time geospatial information (e.g. earthquakes). More complex geospatial questions, like those specific to a user's location, require more complex geospatial computing and cannot yet be answered. For instance, a question like *which hospitals are open now and are also within a 20-minute drive from home?*, cannot be answered simply by retrieving data from databases. Such questions require geospatial analysis and computing, which could be partially supported by leveraging existing APIs. We therefore believe that if skill building could leverage the organizational structure of data, and a corresponding conceptual model that humans have of these types of data, then perhaps computing with them could be easier as well.

4 A Vision for Geospatially-Enabled Voice Assistants

We propose a conceptual framework adopted from Cook and Daniels' software design methodology [4] as a means of facilitating geospatial data discovery and subsequent use to provide answers to users' geospatial questions. Our work formalizing this conceptual model for spatial data is ongoing and is applicable to both GIS and voice assistant environments. We are not proposing an implementation solution; rather, we are proposing a conceptual model to help organize the things that people want to ask about and the computations on geospatial data to answer those questions.

Cook and Daniels' software design methodology is comprised of an essential model, a formal model, and a system model. The essential model is a model of the world built by objects and events used to understand a situation. The formal model (also called the specification model) states what the software will do and formalizes the essential model by mathematical operations. The system model (also called the implementation model) specifies system-level behavior based on the formal model.

In our framework, the essential model specifies concepts about the real world. Since spatial questions are about things in the real world, they are cognitively represented by core concepts of spatial information like *fields* and *networks* [7]. Thus, the procedure to answer a question can be formalized as as a set of spatial operations with mathematical foundations (as a formal model). The information detected from user questions can be used as input for

[15] `https://moz.com/blog/google-organic-click-through-rates-in-2014`

the spatial operations. The spatial operations can then be implemented in a chosen software (as a system model). The results are finally computed by the chosen software and returned to the user as an answer. An example of this framework is shown in Figure 2.

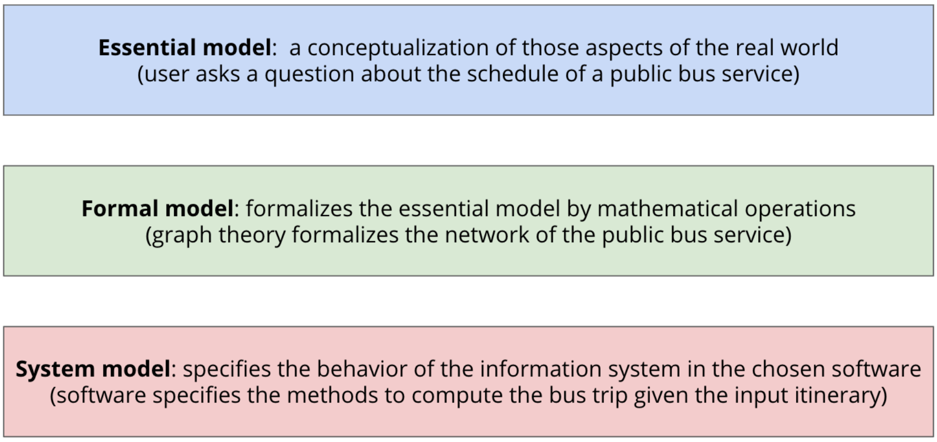

Figure 2 The essential (blue), formal (green), and system (red) conceptual levels.

To operationalize this framework, we need a means of relating human concepts to formal operations and system level commands in a GIS [1]. Kuhn's core concepts of spatial information [7] provide a bridge, specifying concepts in user questions at the essential level and relating them to operations at the formal level. Previous work on question-based spatial computing used data abstraction to relate user questions to computations in a GIS [9].

Progress can be made on the essential and formal models for at least two core concepts: *fields* and *networks*. Fields as an essential model conceptualize continuous phenomena and are characterized by continuous functions from location to theme. Prototypical examples include elevation, temperature, and rainfall. Fields are formalized by map algebra. The field concept allows users to ask questions like *how much did it rain in my neighborhood last night?* Networks are a topological essential model, formalized by graph theory. They allow users to ask questions like *how many bus stops are between my house and downtown?* The system model could take the form of an existing geocomputation API (e.g. GDAL, ArcGIS Online, etc.). Today, architectures of many geospatially enabled portals (e.g. Socrata with QGIS[16], Hub with ArcGIS Online[17]) are already equipped to handle the system model specifications. By formalizing the operations that are to take place on the geospatial data in the portal, today's voice assistant applications move closer to the capabilities of conversational GIS.

The mathematical formalization of fields and networks suggests a manageable set of questions that users could ask of open government data. We surmise that these two concepts, their mathematical models, and the accompanying software packages, could provide an entry point for mapping between user questions and computations, following the architecture illustrated in Figure 2. In this vision, voice assistants serve as a kind of conversational GIS, answering a far broader range of geospatial questions about government.

[16] `https://dev.socrata.com/blog/2016/06/13/geospatial-analysis.html`
[17] `https://doc.arcgis.com/en/hub/sites/explore-data.htm`

Voice assistants following this framework would organize contents based on their spatial concepts, suggesting data and operations to perform on them based on the concepts in a user's question. For example, such a system could parse the previous question *which hospitals are open now and are also within a 20-minute drive from home?*, and recognize that "hospitals" are likely to be objects in a health care data set and determine that "a 20-minute drive" would require a road network data set. A computation would intersect currently open hospitals (stored as an attribute of the open dataset) and a 20-minute roadway service area from the user's home. If suitable open data sets do not exist, the voice assistant could suggest alternatives with similar themes based on the concepts present in the original question.

5 Conclusion

A vast amount of open public data is ready for discovery. Technological advances in voice assistant technology have the potential to actively connect users to developments in their communities. In this paper, we have explored voice assistant applications that governments are developing to improve open public data discovery and use. To address challenges that today's applications face, we have proposed a conceptual framework informed by core concepts of spatial information and structured as an essential, a formal, and a system model. Relating the language of user questions about the world to spatial computations is a step toward improving discovery and use of open public data for users and their communities.

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